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Eight children from each of five age groups, 4, 5, 6, 7, and 8 years, were administered matrix tasks involving two nominal dimensions, color and shape. Nine stimulus cells and six attribute cells made up the apparatus. The attribute cells consisted of three colors and three geometric shapes: the stimulus cells made up a matrix consisting of the nine possible combinations of the two basic attributes. The subjects were asked to perform three operations on the matrix: (1) to define the covered contents of the stimulus cells by looking at the attribute cells, (2) to place the stimuli in their correct cells while being guided by the attribute cells, and (3) to define and fill the attribute cells by viewing the stimulus cells. The results showed that on all three tasks the performance of the 4-year-olds was close to chance, the performance of the 8-year-olds was near maximum, and there was gradual improvement of performance for the ages in between. For subjects 4 to 7 years of age, tasks (1) and (2) were positively related but were independent of task (3). For the 8-year-olds, tasks (1) and (3) were positively related and tasks (1) and (2) were independent. This difference in task relationships is probably due, in part, to differences in the types of verbal mediators involved. (WD)

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CHILDREN'S ABILITY TO OPERATE WITHIN A MATRIX: A DEVELOPMENTAL STUDY

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Abstract

40 pre- and elementary-school children, ages 4, 5, 6, 7, and 8 years, were presented three tasks intended to tap the ability to deal with the extensional and intensional aspects of classification in a matrix format. Stimuli were the nine combinations of three shapes and three colors, set in a matrix, and the six attribute stimuli. Performance on all three tasks increased with age: on all three tasks the performance of the 4-year-olds was little different from chance, whereas the performance of the 8-year-olds was near maximum. Correlations among the three tasks indicated that for younger children (4-7 years) the two tasks intended to tap the extensional aspect of classification were significantly positively related, but were essentially independent of the task intended to tap intensional behavior. For the 8-year-olds, however, the two extensional tasks were independent, while the intensional task was highly related to only one of the extensional tasks. These results are discussed in terms of the older children's "concrete-operational" functioning and of the required production of different kinds of verbal mediators.

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In recent years, considerable attention has been devoted to children's ability to orient (Buttenlocher, 1967), group (Ricciuti & Johnson, 1965), sort (Kofsky & Osler, 1967), and classify (Charlesworth, 1968; Sigel & Olmsted, 1968) objects. In large part, the empirical research was dictated by Piaget's theory of cognitive development (Inhelder & Piaget, 1964). In a few instances (e.g., Kofsky, 1966), the primary purpose of the research was to validate the sequence of development proposed by Piaget; in others, the purpose was to assess the implications of Piaget's theory in areas not specifically discussed by him.

The ability to classify objects and to assign them to categories is an important cognitive skill. One of the most interesting manifestations of this skill is the child's ability to deal with two aspects of a situation at a time. An example of this type of operations is what Piaget has referred to as "bi-univocal multiplication of classes" (Flavell, 1963). One reasonable approach to studying how children develop this ability is to examine their behavior in a logically complex classification task: the matrix, which involves the simultaneous ordering of two dimensions.

Young children's performance on a task with a matrix format has been infrequently studied. In one recent study by Bruner & Kenney (1966), children 3 to 7 years were presented with nine plastic beakers, arranged in a 3 x 3 matrix; the beakers varied in height and width. The children were asked to: (a) replace beakers removed from the matrix, (b) reproduce the matrix when the beakers were scrambled, and (c) transpose the matrix (the thinnest, shortest beaker was placed in the lower right cell rather than the upper left). Virtually all of the 5-, 6-, and 7-year-olds succeeded in replacing the beakers, but half of the 3- and 4-year-olds failed when the diagonal beakers were removed. The ability to reproduce the matrix in its original form also increased with age, but performance

lagged behind that on the replacement task at all ages. The transposition task proved most difficult of all--only the 7-year-olds succeeded.

Bruner & Kenney's task utilized two ordinal dimensions--height and width. It would seem that either prior to or concurrent with the ability to deal simultaneously with two ordinal dimensions, should come the ability to deal with non-ordinal or nominal dimensions. These dimensions represent the kinds of things a young child is likely to come in contact with during his every day experience: kinds of food, types of toys, colors, shapes, animals, etc.

In a recent study, Smedslund (1967) used the matrix format but studied two dichotomous nominal dimensions. Only two age groups of children were studied. The performance of 8-year-olds was markedly superior to that of 6-year-olds in a task tapping the ability to deal with the extensional aspect of double classification.

The present study was undertaken to provide some developmental information about children's ability to deal with such situations. Piaget's observations and experiments suggest that this ability should not completely emerge until 7 or 8 years of age (the concrete-operational period). (However, if we were to find that 6-year-olds could handle the tasks, this would be irrelevant to his theory).

This study is one of the first of a series that gather data from a relatively new project, the Primary Education Project (PEP), whose purpose is the construction and validation of a pre-school cognitive curriculum (Resnick, 1967). The ultimate aim of the Project is to provide "disadvantaged" pre-schoolers with the cognitive skills prerequisite to successful academic performance in elementary school. Classification and problem solving skills comprise one substantive area of research and curriculum emphasis. Prior to specifying a curricular sequence, it was first necessary to obtain more general data about the natural development of certain specific abilities--such as the ability to operate within the format of a matrix.

Method

Subjects

Forty pre- and elementary school children, eight at each of five age levels: 4, 5, 6, 7, and 8 years participated in the study. The children came from predominantly lower-middle/upper-lower socioeconomic backgrounds. Teachers' and administrators' estimates suggested that the children were mainly average or slightly below in intelligence. The children all attended an experimental school in a "disadvantaged" area of Pittsburgh. As can be seen from the description of the sample in Table 1, the within-age variation

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was quite small and there was no overlap between age levels. At each age level, approximately half of the Ss were boys and half were girls. Twenty-seven of the children were Negro, but some white children were included at each age level.

Apparatus and Stimuli

The apparatus consisted of 15 opaque white lucite boxes, set in a plastic tray. Each box was 3 inches square, 1 inch high, and had a 3 x 3 inch opaque lucite cover with a handle on it.

Stimuli were pieces of cardboard varying in color and shape. Since a matrix format was used, different stimuli were employed for the matrix cells and the attribute cells (row and column headings). Stimuli for the "shape" attribute cells were a circle, a square, and a triangle; these were buff colored and approximately 2-1/2 square inches in area. The stimuli for the "color" attribute cells were three different irregularly shaped pieces (one red, one blue, one yellow) approximately the same size as the other stimuli. Stimuli for the matrix cells were 3 circles (one each of red, blue, and yellow), 3 squares, and 3 triangles. When all boxes were uncovered and filled with the appropriate stimuli, the situation looked approximately like Figure 1.

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Procedure

Ss were tested individually and were taken by E from the classroom to a small experimental room. E seated herself next to S at a table on which were the experimental materials. Each S was given the same set of tasks and instructions.

Prior to the experimental tasks, a number of preliminary tasks were given. E took three empty boxes, placed the nine matrix stimuli in a random order on the table and gave the following tasks:

1. Naming colors and shapes: The red circle, blue square, and yellow triangle were pointed to in order, and to each, S was asked: "What color is this?" Then the blue triangle, yellow circle, and red square were pointed to, and to each, S was asked: "What shape is this?"

2. Undirected sort: "Here are some objects. Put all of them into these boxes so that each box has all the same things in it." A sort was judged consistent if either three shapes of the same color or three colors of the same shape were put into each of the three boxes.

3. Color sort: The stimuli were removed from the boxes and again placed in a random order. "Now, put the objects into the boxes by their color. Put all the reds in one box, all the blues in another box, and all the yellow in the other one."

4. Shape sort: The same procedure was used, but instructions varied: "Now, put the objects into the boxes by their shape. Put all the circles in one box, all the squares in another box, and all the triangles in the other one." Both this sort and previous one were judged consistent if S performed according to instructions.

After these were completed, the nine-cell matrix and its six attribute cells were constructed, and the main experimental tasks given. The first two tasks were chosen because they seemed to entail the essence of matrix operations, the conjunctive concept. In the first task, the child had to define the attribute values of the object belonging in a particular cell; in the second, he had to locate the cell in which a particular object belonged. To be sure, these are two sides of the same coin, the "extensional" aspect of classificatory behavior, but it was felt that they might entail somewhat different operations.

Define object (task DO). The matrix cells were filled with the nine

stimuli and covered; the attribute cells were filled, but open and visible to the child. At the side of the matrix were duplicates of the nine matrix stimuli, arranged in a random fashion. The attribute cell containing the red "blob" was pointed to: "This color is red. That means that everything in this column (E ran finger down column) must be red." This procedure was done for the blue and yellow attribute cells also. Then, the square attribute cell was pointed to: "This shape is a square; that means that everything in this row must be a square." Similar instructions were used for the circle and triangle attribute cells. "In each box there is an object that has a shape and a color. I am going to point to a box. Inside it there is an object. You must guess what shape it is and what color it is." In a different random order for each child, each cell of the matrix was pointed to and S was asked: "What's in this box?" The child then made a verbal response (guess). E then asked S to choose the object from the random array. The child pointed to one of the stimuli, E recorded his choice and told S that he could pick up the cover to see if he was correct. S was then told to put the cover back, and a similar procedure was then used for the remaining eight cells.

Locate cell (task LC). The matrix cells were empty and uncovered; the attribute cells were filled and uncovered. A random array of the nine matrix stimuli was placed at the side. The same preliminary procedure as in task DO was used, demonstrating the attribute cells. Then E said: "Now, I'm going to show you an object. You put it in the box where it belongs." E showed S each of the nine stimuli from the array in a random order; and after S put it into the box, E recorded the choice, removed the stimulus, put it back in the array, and showed the next stimulus. This task was given twice: once with the shape attribute cells on the vertical axis, and once with the color attribute cells on the vertical axis.

Abstraction of common property (task ACP). This task was intended to tap the "intensional" aspect of classificatory behavior, i.e., the common property defining the members was to be specified. The matrix cells were filled and uncovered; the attribute cells were empty but covered. E said to S: "Each row (column) has something in it that tells

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you what is the same about the row (column). Look at each row (column) carefully and guess what is in the covered box at the side (top)." Each of the six attribute cells was pointed to in a random order. After S gave his verbal responses (which were recorded), the covers to the attribute cells were removed. E said: "I will give you a color or a shape. You put it at the beginning of the row or column that has the same color or shape."

In addition to the three experimental tasks, an "undirected" matrix sort was given: only nine boxes in a 3 x 3 format were used; all were empty and uncovered. The nine stimuli were placed in a random array next to the boxes. S was told: "Here are some objects. Put one object into each of the boxes the way you think they ought to go."

Results

Preliminary sorts. The data for these sorts are presented in Table 2, in terms of the number of Ss (out of eight) at each age level making completely

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consistent sorts. Although there were fewer consistent sorts at the 4-year level, chi-square tests corrected for continuity indicated that there were no significant age differences (all X^2's < 1.00). All but one of the children, a 4-year-old, correctly named all three colors and all three shapes. Since none of the children made more than one error in any of these preliminary sorts, there appeared to be little age difference in the ability to sort on the color and shape dimensions individually, nor in the ability to name the particular values used.

Experimental tasks. Simple 5 (Age) x 8 (Ss/cell) analyses of variance were performed on the mean number of correct responses in each of the three experimental tasks (DO, LC, and ACP). These data are presented in Table 3.

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Task DO. As in task ACP, there were virtually no discrepancies between Ss' verbal "guesses" and their overt stimulus choices, thus, no further analyses were performed on the verbal measures. The mean number of choices (out of nine possible) in which both shape and color were correct increased significantly as a function of age. Scheffe confidence intervals (.05) indicated that the 4- and 5-year-olds made significantly fewer correct responses than did the 7- and 8-year olds; none of the other comparisons was significant. It should also be noted that only the performance of the 4-year-olds was not significantly different from chance ($t = 1.32$, $df = 7$, $p > .10$). On task DO, as well as on all other tasks, there were no sex or race differences in mean number of correct responses (t's < 1.00).

Task LC. Since there were no significant differences between the two presentations (all t's < 1.00), the scores were summed. The mean number of choices (out of 18 possible) in which both the shape and the color value were correct, as in task DO, increased significantly as a function of age. Scheffe confidence intervals (.05) indicated that ages 4, 5, and 6 were all significantly different from age 8; none of the other comparisons was significant. The performance of all age groups was significantly above chance ($t \geq 4.51$, $df = 7$, $p < .01$).

Examination of the protocols indicated an interesting phenomenon. Some children, when asked to put a particular object in one of the boxes, would place all of the objects in only one row or column of boxes. For example, if the horizontal axis defined the color dimension, some children would place the three blue objects in the top box of the blue column, the three red objects in the top of the red column, and the three yellow objects in the top box of the yellow column. The frequency of this behavior was tabulated, and it was found that regardless of which axis defined the color dimension, six of the eight youngest children performed in such a fashion, whereas only one child at the most did so at any of the other age levels. This behavior on the shape dimension was performed by only one 4-year-old and one 5-year-old.

Task ACP. Although there was a consistent linear increase from age 4 to 8 in the mean number (out of six possible) of correct attribute

choices, the analysis of variance yielded only a marginally significant age effect. Scheffe confidence intervals (.05) indicated that there were no significant differences between any of the age groups.

Additional data. A somewhat different picture of the data emerges when one looks at the number of children at each age level who demonstrated optimum or near-optimum performance. Each S was considered as having "passed" a task if he performed with no more than one error. A "passing score" would thus be 8 on task DO, 16 on task LC, and 5 on task ACP. The number of children at each age level "passing" each task is presented in Table 4. These data indicated different trends than did the group mean data. All four chi-square analyses (corrected for continuity) were

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significant ($\underline{X}^2 \geq 4.10$, $\underline{df} = 1$, $\underline{p} < .05$), indicating that in all four tasks (three experimental and the undirected matrix sort), very few children of the four youngest age levels performed adequately, while most of the oldest children did.

Using the same criterion for "passing", the number of the 3 experimental tasks passed by each S is presented in Table 5. Most of the children at the four youngest age levels failed all tasks, whereas none

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of the oldest children did (Fischer's exact $\underline{p} = .043$). On the other hand, half of the oldest children passed all three tasks, whereas none of the 4-, 5-, or 6-year-olds, and only one 7-year-old did. Thus, the intra-subject data seem, at least in one sense, to be in essential agreement with the inter-subject data: all experimental tasks were relatively difficult, if not impossible for children at the four youngest age levels; for the oldest children, however, the tasks were relatively easy and appropriate to their level of cognitive functioning.

Correlations were computed among the three experimental tasks for the entire sample, for the two youngest ages combined, for the 6- and 7-year-olds combined, and for the 8-year-olds (since their performance

in the tasks was markedly different from that of the rest of the Ss). These correlations are presented in Table 6. Significant positive

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intercorrelations among the different age groups were not uniform. For the four youngest age groups, tasks DO and LC appear to be tapping the same kind of functioning, whereas tasks DO and ACP appear to be tapping different functions. For the 8-year-olds, on the other hand, tasks DO and LC appear to be independent, whereas DO and ACP appear to have quite a bit in common. The differences between the two inter-task correlations for the 4-5 and 8-year olds ($r_{DO\text{-}ACP} - r_{DO\text{-}LC}$) were both significant (t for dependent correlations ≥ 2.93, $df \geq 5$, $p < .05$), but obviously in different directions.

Discussion

These results indicate that the ability to operate within a matrix of two nominal dimensions improves from very little ability at age 4 to nearly maximum at age 8. If the group mean data are considered, the abilities to deal with both the extensional and intensional aspects of matrices increase gradually through age 8. If one considers the number of children at each age level performing optimally on the various tasks, however, it appears that these abilities are fairly minimal through age 7, and become near maximal at age 8. Whereas both of these kinds of data are in agreement with Piaget's research and theory, the latter finding is also congruent with other such rapid age shifts in other kinds of behavior (White, 1965).

The data for the 4-year-olds also indicate that if a young child is given a task that is very difficult for him, if the situation allows (as it does in task LC) he will centrate on one dimension, ignore the other, and will sort only on the centrated (which is usually his "preferred") dimension. This type of "color dominance" has been found before in other tasks (Suchman & Trabasso, 1966).

That the 8-year-olds performed relatively better on the two extensional tasks than on task ACP suggests that the ability to deal with

intensional aspects of the matrix is developmentally more advanced. Tasks DO and LC, in addition to tapping extensional behavior, required that dimensions be used conjunctively, whereas task ACP required that they be used disjunctively (attribute cells were either a color or a shape). Previous studies have also found that the conjunctive concept is easier to teach and deal with than is the disjunctive concept (Bruner, Goodnow, & Austin, 1956; King, 1966).

The different patterns of task intercorrelation for the various ages require further mention. For the younger children (4-7 years), tasks DO and LC were highly related and were both essentially independent of task ACP. In retrospect, this is not surprising. If the ability to deal with intensional aspects of a situation (such as abstracting a common property) is developmentally more advanced, it does not seem unreasonable that, for younger children, measures of intensional and extensional ability would be independent. Similarly, if the young child has some "extensional" ability, two measures of that ability should be positively correlated.

For the oldest children, performance on task DO was highly correlated with that on task ACP. Again, this seems reasonable. If it is assumed that the 8-year-olds were functioning on the "concrete-operational" level (while the younger children were functioning in a more "pre-operational" mode), then one might reasonably expect that intensional and extensional ability would be related. The child should be able to shift his cognitive focus from one operation (defining components) to another (abstracting from the components); he should be able to consider both color and shape simultaneously, or when appropriate, ignore whichever dimension is irrelevant. These kinds of abilities reflect Piaget's concepts of reversibility and decentration, and are characteristic of the child functioning on the concrete operational level.

Why, then, was there no significant relation between task LC (the other extensional task) and ACP for the oldest children? And why, for that matter, was there no significant relation between the two tasks that supposedly tapped the same kind of ability (tasks DO and LC)? One possible source of explanation may be found in our procedure. In both

tasks DO and ACP the child was required to make a verbal response (guess) prior to making the motor response of selecting or placing. No such verbal response was required in task LC: all S had to do was to make the motor response.

If, as might easily be argued, the performance of the 8-year-olds was in large part verbally mediated, and both task DO and ACP demanded that S produce similar mediators for each (overt labeling of the unseen stimulus), then those tasks ought to be positively correlated. However, if two tasks required the production of different kinds of mediators, or one required an overt verbal label (DO, ACP) and the other did not (LC), then one would not necessarily expect them to be correlated. The pattern of inter-correlations confirm this post hoc reasoning. Further support comes from a recent study by Smedslund (1967). His data indicate that while the performance of 8-year-olds in a 2 x 2 matrix task is relatively unaffected by whether the objects are covered or uncovered, it is affected by whether or not the task requires an overt labeling response by S.

Although the behaviors examined were only a limited sample, the results of the present study indicated that: (a) the abilities to deal with the extensional and intensional aspects of classification within a matrix increase as a function of age, but prior to age 8 these abilities are fairly minimal and essentially independent; (b) these two aspects of behavior are highly correlated and well integrated into the cognitive system of 8-year-olds; and (c) tasks that are intended to tap the same kinds of abilities may not do so if they require the child to produce very different mediators.

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Table 1

Description of Sample

Age Group	N	Mean Age (months)	S.D.	Range	Sex		Race	
					Boys	Girls	Negro	White
4	8	54	6.6	48-59	5	3	4	4
5	8	64	2.7	61-67	3	5	6	2
6	8	77	3.7	72-81	4	4	4	4
7	8	89	3.6	86-93	3	5	6	2
8	8	102	2.5	98-107	5	3	7	1

Table 2

Number of Ss Making Consistent Preliminary Sorts

Age Group	N	Type of Sort		
		Undirected	Color	Shape
4	8	5	5	5
5	8	5	7	7
6	8	6	7	8
7	8	7	8	7
8	8	8	8	8

Table 3

Mean Number of Correct Choices on the Three Experimental Tasks

Age Group	N	Task DO (9 possible) $\bar{X}$	Task DO (9 possible) SD	Task LC (18 possible) $\bar{X}$	Task LC (18 possible) SD	Task ACP (6 possible) $\bar{X}$	Task ACP (6 possible) SD
4	8	1.53	0.76	5.25	2.05	1.87	1.19
5	8	2.87	2.43	6.75	4.49	3.00	2.01
6	8	4.87	2.81	7.38	3.50	3.25	1.76
7	8	5.37	2.45	8.25	4.71	3.75	1.72
8	8	8.00	2.46	14.75	5.07	4.50	1.27
F (4/35)		9.45		5.59		2.20	
		$p < .01$		$p < .01$		$p < .10$	
Scheffe .05 Confidence Interval		3.73		7.02		3.02	

Table 4

Number of Ss at Each Age Level "Passing" Each of the Various Tasks

Age Group	N	DO	LC	ACP	Undirected matrix sort
4	8	0	0	1	0
5	8	1	1	2	1
6	8	2	1	2	2
7	8	2	1	2	2
8	8	7	6	5	5

Table 5

Number of Ss at Each Age Level "Passing" the Three Experimental Tasks

Age Group	N	Failed all 3	Passed 1/3	Passed 2/3	Passed all 3
4	8	7	1	0	0
5	8	5	2	1	0
6	8	5	1	2	0
7	8	5	2	0	1
8	8	0	2	2	4

Table 6

Intercorrelations among the Three Experimental Tasks

Age Group	r between tasks			df
	DO-LC	LC-ACP	DO-ACP	
4-5	+.73**	+.38	+.07	14
6-7	+.50*	+.18	+.11	14
8	-.15	+.00	+.85	6
All Ss	+.62**	+.37**	+.46**	38

*p < .05

**p < .01

Figure Captions

Fig. 1. Stimuli for the Three Experimental Tasks.